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SUSTAINED OPERATIONS RESEARCH: A BLEND OF PSYCHOLOGY AND PHYSIOLOGY

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PROGRAM SUMMARY

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SUSTAINED OPERATIONS RESEARCH: A BLEND OF PSYCHOLOGY AND PHYSIOLOGY

INTRODUCTION

Research in many modern laboratories has become interdisciplinary, often blending psychologists, physiologists, physicians, and members of other related technical disciplines into teams which can direct a more comprehensive approach to the study of a problem area. This is particularly true when realizing that the training of most scientists is far from standardized, often very specialized, and the subject matter of investigation is usually far too complex for unilateral approaches. This becomes extremely relevant for problem areas of interest where highly-trained individuals and complex machine systems perform tasks interdependently to accomplish a given mission. Additionally, this interdisciplinary evolution in science is driven by an explosion in technological and methodological advances which enable scientific investigators the capability to measure human functioning at a near comparison to that of machine- system monitoring by today's engineering technology. It is important to note also that as interdisciplinary studies have gained in popularity, theories incorporating physical and behavioral hypothesis have gained strength due to approaches which focus multiple measures on single factors.

The study of military sustained performance/operations (SUSOPS) is a subject matter of interest which is typical of a team approach to scientific investigation. Modern hardware/systems used by the military, for example, can project the human component of the man-machine enterprise into operational scenarios and task requirements previously thought to reside only in the fantasies of science fiction writers. The description of the quality and duration of performance under such conditions has received much attention in recent years, and has been presented at previous symposia. Now, the focus is upon determining the methods/means for sustaining and/or enhancing complex performance when conducted for extended periods in various hostile environments. Sustained/continuous work research now frequently includes

related fields of study. These environmental and interdisciplinary areas of study are typically sleep deprivation, work load, exercise physiology, biological rhythms, cognitive psychology, and electrophysiology.

The purpose of the symposium was to present findings exemplary of some of the more recent interdisciplinary SUSOPS studies conducted at the Naval Health Research Center. Following the paper presentations, problems and knowledge associated with the implementation of SUSOPS studies and the day-to-day management of diverse interdisciplinary science teams were the focus of a participatory discussion.

The symposium began with Dr. Banta's presentation concerning the Navy's Sustained Operations Research Program, and the field performance assessment technology development stimulated by the unique environments in which the Navy operates. Next, was Mr. Neil Sjoholm's discussion of sustained heavy work load effects on body temperatures, and the subject's perception of thermal effects. Closely related to, and following Mr. Sjoholm's presentation, was Dr. Sucec's study of perception of sustained work effort and actual energy cost experienced by the subjects. Reaction time, work effort, and thermal perception as a function of wearing the Navy's new shipboard combat helmet and face shield for sustained periods of time was the subject of Mr. Jay Heaney's paper. Dr. Kobus presented the results of his work using event-related potential techniques to study attention and performance during sustained tasks. Dr. Englund presented the results of measures of medical and psychological problems which typically have plagued military participants over a series of sustained operations studies. Lastly, in his absence, an abstract of Mr. Chris Leake's timely results of our Navy SUSOPS study of physiological reactivity and optimism as a function of stress was presented.

The authors wish to thank Ms. Gloria Held for her significant contribution in the editing and preparation of this manuscript.

PERFORMANCE ASSESSMENT DURING VARIED NAVY SUSOPS: COGNITIVE, PHYSICAL, AND PHYSIOLOGICAL

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The nature of today's military missions has developed interest, and often pointed questions, such as: "What affects human performance in a military setting?" That is, what interferes with a sailor/soldier/airman's capability (both cognitive and physical) to perform his or her duty, and to perform that duty in a correct and efficient manner?

As you might recall from recent news reports describing various events aboard U.S. Naval vessels during the past year, such interests and questions have become associated with the broad terms of "Stress and Fatigue." Stress and fatigue are multifaceted phenomena that occur every day during military operations: physical fatigue, multi-tasked/cognitive overload, sleep loss, adverse environments (heat/cold altitude/acceleration/water immersion/motion/noise) -- to name a few. Where these threaten human performance acutely, repetitively, and chronically is during sustained and continuous operations (SUSOPS).

The "real world" of military operations does not include scheduled tea breaks, naps, thermostatic-controlled environments, taxis, or even hotel porters to carry one's luggage. The real world necessitates that our military personnel constantly train and be prepared to perform under any condition. Therefore, this mandates that the research and development community constantly attempt to quantify the environment within which personnel have to work, and determine how that environment affects human response. This is in order to develop new techniques, devices (black boxes), guidelines, and training scenarios that will enable the individual and/or, sometimes more important, the total mission, to maintain or even have enhanced performance.

To enable you to appreciate the magnitude of such tasking, I would like to present a synopsis of the U.S. Navy SUSOPS environment, how we attempt to assess performance, and a few (but certainly not all) issues that surround such "Field Research."

The Navy is a service in which all areas of military operations occur:

-- At sea
-- Under sea (both in and out of a vessel)
-- In the air (fast attack and hover), and
-- Land-based.

Selected job-tasks and performance requirements within these communities cross over an unlimited list of cognitive and physical performance concerns, especially during SUSOPS:

1. Maintenance of vigilance and attention:
   -- Endless hours of target tracking;
   -- Continuous prioritization of multiple inputs.

2. Anxiety/fear; often included in extended periods of General Quarters (GQ).

3. Physical exertion, not only in combat, but in training and emergency response (e.g., fire fighting and damage control).

4. Exposure to adverse environments:
   -- Heat loads (sometimes greater than 130^{o} F)
   -- Acceleration
   -- Pressure
   -- Motion

5. Constant changing man/machine interface (Human Factors if you prefer):

   -- New helmets: for long-term wear for ballistic protection.

   -- Visual enhancements: wearing night vision goggles (NVGs) during low level flight.

   -- Cognitive/physical work loads when wearing Chemical Defense ensemble.

The laboratory affords us an opportunity to segregate specific performance responses in a very controlled setting.

- -- Treadmill: aerobic/anaerobic capacity
- -- Physical strength
- -- Cognitive Testing: for measurement of single and dual tasks with/without event-related potentials (ERPs)
- -- Many paper/pencil tests: still frequently used in many studies.

The laboratory is an excellent arena to initiate the means to understand the basic science question and as a means of filtering the confounding variables that define human performance. In order to maintain control, yet capture the realism of the operational environment, we develop varied simulations and attempt to provide the stress/work loads found routinely in the Fleet, especially during irregular work/rest sustained conditions.

- -- Cognitive: aviation and Command Information Centers (CICs)
- -- Altitude
- -- Motion/spatial disorientation
- -- Impact/acceleration (repeated gravitational "G" loading)

However, only in the "field" environment can we truly define the confounding variables of sustained operations, and measure the operational relevance and feasibility of laboratory developed countermeasures. It is the real world where we define the magnitude and complexity of operational synergistic loading (multi-stressors) on human performance. Also, it is the real world in which the Fleet Commanders expect immediate feedback in order to develop mission tactical planning and life-saving guidance. However, because of the everyday, never-ending environmental changes and individual differences -- normal laboratory practices in the field become significant challenges:

- -- We are quick to face issues such as having control groups in a study;
- -- Acquiring a large enough number of volunteers ("N");

-- "Non-changing" repeated measures;

-- Learning curves and the Hawthorne effect.

Less scientific, yet, just as vital concerns:

-- Electric power and refrigeration;

-- Hardened (sailor-proof) and environmental protected equipment;

-- Duty schedules, sleep schedules;

-- Mechanical breakdowns impacting investigative protocols.

And finally, the ability to empirically quantify success or failure during real world activities:

-- Imagine attempting to tap every change in a pilot's flight controls during night refueling following 30 hours of continuous flight or repeated air combat maneuvers.

-- Psychomotor function assessment during ordinance placement of combat swimmers following extended hours of underwater immersion in below zero degree water temperatures.

-- Identifying efficiency of tactical planning and response following 48 hours of continuous "real" combat.

Current techniques and state of the art equipment allow us to correct for some of these difficulties:

-- Investigator deployment on the military mission, and real time data collection during job task performance in the actual environment.

-- Utilization of solid state "real time" recording devices that are unaffected by the environment that can be hooked-up to the individual prior to going on duty.

-- Telemetry systems: man and machine mounted; such as during parachute testing and aircraft flight.

-- On-site basics: blood/urines to include pre-during-post watch standing paper/pencil and computerized cognitive test batteries.

While we continually attempt to develop improved field research tools and techniques, our best approach has been:

1. Go to the field to "take the picture." Identify the problems.

2. Laboratory-controlled environment to assess/develop prospective countermeasures.

3. Return to the field to assess countermeasure effectiveness.

The sustained military operational environment is a unique and very challenging laboratory. A laboratory unlike anything we have experienced before. The approaches necessary to accomplish the objectives and test the hypotheses are frustrating indeed. However, obtaining the goals, and being able to deliver life saving, and when necessary, war winning, products make "SUSOPS" human performance investigation exciting research.

EXERCISE, PACKLOAD, AND CLOTHING
EFFECTS ON CORE TEMPERATURE
AND TEMPERATURE PERCEPTION

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ABSTRACT

Sixteen, fit male subjects with a mean age of 22.8 years (±3.2), and a mean height and weight of 179.4 cm (± 6.3) and 74.1 kg (± 9.3), respectively, walked on a horizontal treadmill at 3 mph for 20 minutes out of each hour (one mile) for up to 12 hours (total distance of twelve miles). Subjects wore either regular combat clothing or chemical defense clothing, and carried packloads of varying weight (0, 25%, 50%, and 75% of body weight). A repeated measures design was employed with the packload and uniform randomly assigned. Core temperature was measured using a continually worn rectal probe, and forehead, chest, and thigh skin temperatures were measured with a Yellow Springs Instruments (YSI) tele-thermometer. Subjects' temperature perception (TP) was determined with the United States Army Research Institute of Environmental Medicine (USARIEM) Thermal Perception Scale. Temperatures were recorded eight times during the 20-minute treadmill walk, and TP values were obtained during the first and last three minutes of each 20-minute exercise session. It was found that both clothing and packload had a significant effect on rectal temperature ($P < .01$), that temperature increases ranged from .12-.36°C during the treadmill walks, and that the rectal and the three skin temperatures taken were not highly correlated with TP (coefficients ranged between -.24 and .49). It was concluded that rectal temperature does not increase to levels associated with thermoregulatory distress when subjects walk for 20 minutes out of every hour for 12 hours while carrying up to 50% of their body weight, or carrying 75% of their body weight for six hours under ambient conditions (75°F and 50% relative humidity). Also, none of the temperature measures taken are highly correlated with temperature perception.

This material was previously presented at the 1989 Medical Defense Bioscience Review, Johns Hopkins University, August 5-7, 1989, and published in the Proceedings of the 1989 Medical Defense Bioscience Review, U.S. Army Medical Research Institute of Chemical Defense.

INTRODUCTION

It has been shown that military personnel performing physically-demanding tasks cannot work as long while wearing chemical warfare clothing (CWC) as opposed to combat clothing (Avellini, 1983). One factor contributing to the decreased work time is the increase in body temperature caused by the body's inability to cool itself while inside CWC. Few studies have determined how accurately soldiers can subjectively determine body temperature while wearing CWC. It is not known whether the enclosed, presumably humid environment of CW clothing interferes with the ability to perceive body temperature. If a person's ability to perceive temperature is altered in CWC, they may be unable to avoid thermoregulatory distress. This paper reports the effects of packload and clothing on core temperature and temperature perception.

METHODS

Subjects for this study were 16, healthy male volunteers. The mean age, height and weight (± s.d.) of the subjects was 22.8 years (± 3.2), 179.4 centimeters (± 6.3) and 74.1 kilograms (± 9.3), respectively. All subjects completed an informed consent form, and were made aware of the purpose of the study. Maximal oxygen uptake (VO_2 max) was determined using the Tri-Service protocol consisting of a constant 7 mph pace with 2% increases in grade every two minutes until the runner reaches exhaustion. The mean (± s.d.) VO_2 max for the subjects was 61.5 ml/kg/min (± 3.0). Body composition, which was determined by a six-site skinfold method developed by Yuhasz (1974). Mean (± s.d.) percent body fat for the subjects was 10.3 (± 3.3). Each subject walked on a level treadmill at 3 mph for 20 minutes out of each hour (one mile) for up to 12 hours (total distance of 12 miles). Subjects wore either regular camouflage combat clothing (Cammies) or MOPP4 CW clothing (MOPP), and carried packloads of 0, 25%, 50%, and 75% of bodyweight (BW). A repeated measures design was used (each subject performed eight different walks), and the packload and clothing conditions were randomly assigned. At the 75% of BW load, subjects performed six, 20-minute treadmill walks, instead of the usual 12, 20-minute walks. This was done to reduce the chance of injury to the subjects. During the 20-minute treadmill walking period, body temperatures

were measured with a Yellow Springs Instruments (YSI) Model 47TF Scanning Tele-Thermometer. Temperatures taken were Rectal (T_r) with a 6.35 centimeter probe, Head Air (10mm above head), Skin Forehead (immediately below hairline), Chest (right side deltoid fold) and mid-front thigh. Two measures were taken at each site every five minutes for a total of eight measures taken at each site every 20 minutes. Temperatures were not measured during the 40 minutes of each hour that subjects were not walking on the treadmill. All tests were performed at the San Diego State University Exercise Physiology Lab under ambient conditions (approximately 75^{o}F and 50% relative humidity). Subjects were allowed to drink as much water as they wanted, and the amount of water consumed was recorded. Temperature perception (TP) was obtained during the first two minutes of exercise (TP1) and during the last two minutes of exercise (TP2) of each 20-minute walking session. TP measures were taken using the United States Army Research Institute of Environmental Medicine (USARIEM) Thermal Sensation Scale (Yeager et al., 1987) seen in Appendix A.

RESULTS

Rectal Temperature data was divided into four, five-minute segments. Rectal 1 refers to mean rectal temperature for the first five-minute segment of the 20-minute treadmill session, Rectal 2 refers to the second five-minute segment; Rectal 3 the third, and Rectal 4 the fourth and final five-minute segment. Rectal temperature results can be seen in Table 1 and Figures 1-4.

Table 1. Mean Rectal Temperatures While Carrying Varying Packloads (^{o}C)

	Cammie				MOPP			
	0	25%	50%	75%	0	25%	50%	75%
Rectal 1	37.15	37.25	37.36	37.35	37.38	37.39	37.48	37.55
Rectal 2	37.17	37.26	37.40	37.39	37.39	37.39	37.48	37.64
Rectal 3	37.21	37.32	37.50	37.50	37.43	37.45	37.55	37.73
Rectal 4	37.27	37.39	37.71	37.71	37.53	37.52	37.62	37.83

Figures 1-4. Mean rectal temperatures while walking on a treadmill at 3 MPH at 23.9°C and 50% relative humidity:

Figure 1

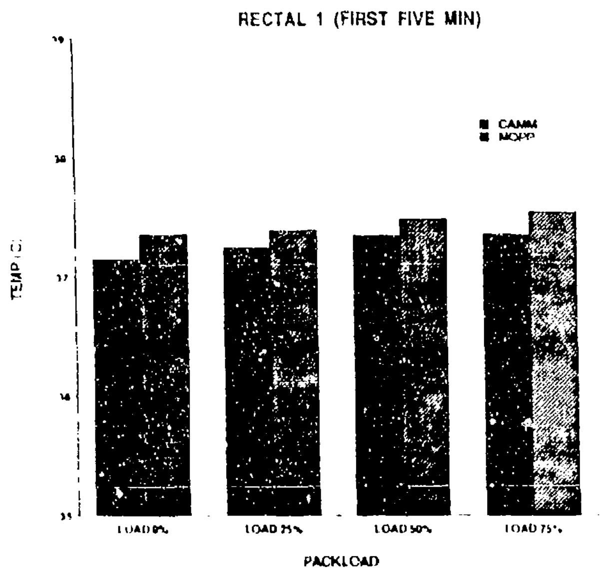


Figure 2

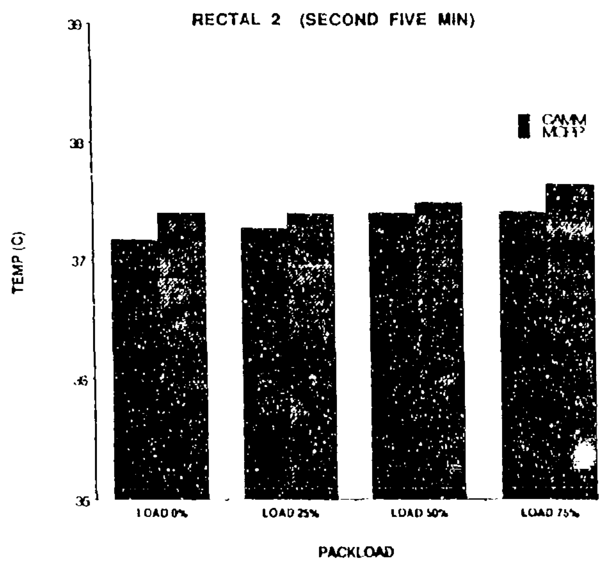


Figure 3

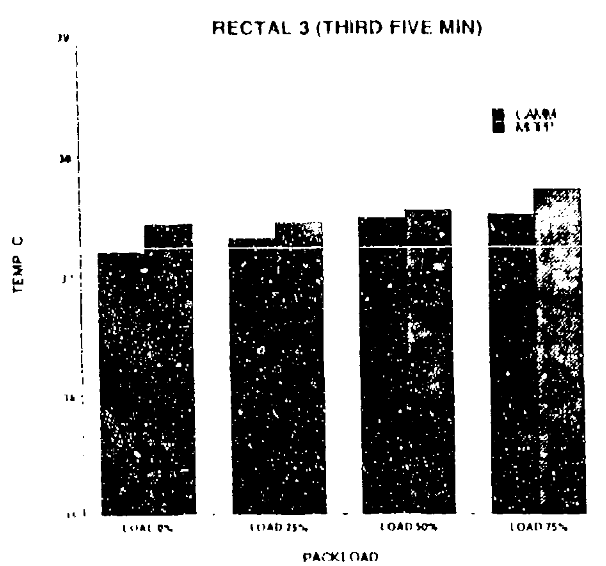
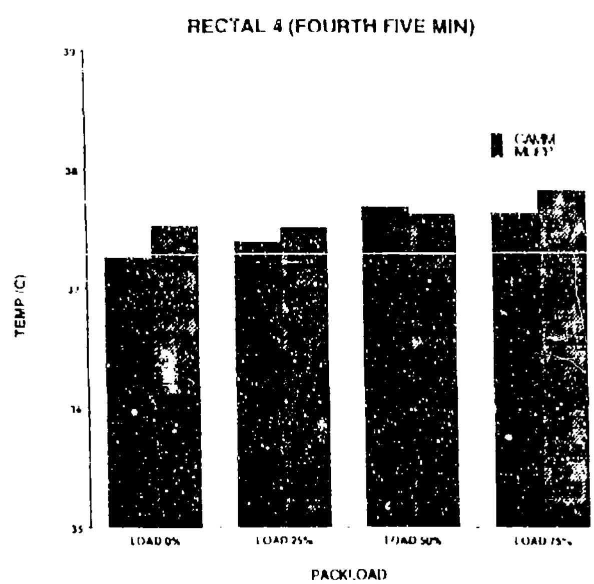


Figure 4



Pearson's correlations between rectal temperature and TP are shown in Table 2 below:

Table 2. **Correlation Coefficients Between Rectal Temperature and Temperature Perception**

	Cammie		MOPP	
	TP1	TP2	TP1	TP2
Rectal 1	.21		-.24	
Rectal 4		.39**		.24

** = $p < .01$

Note: TP was not recorded during Rectal 2 and Rectal 3 periods.

For mean temperature data, a 2 x 4 within subjects ANOVA with two levels of clothing (MOPP and Cammie) and four levels of packload (0, 25%, 50% and 75% of bodyweight) was used to analyze the data. A significant effect for clothing and packload was found ($p < .05$). There was no clothing-packload interaction.

DISCUSSION

Rectal temperature increases ranged from .12-.36^{O}C, and the highest mean temperature recorded was 37.83^{O}C. This is expected as it is well known that as workload is increased, rectal temperature will also increase (Astrand and Rodahl, 1977). Also, Avellini (1983) and Tilley et al.(1981) have shown that rectal temperatures are higher when subjects wear CWC as opposed to combat clothing. From these data, it appears that rectal temperature does not increase to dangerous limits when subjects march for 20 minutes out of every hour for 12 hours carrying up to 50% of their body weight, or carrying 75% of their bodyweight for six hours under ambient conditions.

As can be seen in Table 2, rectal temperature is not highly correlated with temperature perception. This agrees with the findings of Gagge et al. (1969) who found that temperature sensation has a correlation of .28 with rectal temperature in subjects performing steady-state exercise. Gagge et al. (1969) also found mean skin temperature has a correlation of .73 with temperature perception, and theorized that, "During steady exercise, temperature sensation is governed primarily by the temperature sensors of the skin."

Mean skin temperature in the Gagge et al. (1969) study was determined from ten different sites. In this study, skin temperature was measured at three sites: forehead, chest, and front thigh. These three sites do not make up an established mean skin temperature equation, so a mean skin temperature-thermal perception correlation was not determined in this study. However, correlations were performed between individual skin temperatures and temperature perception. These results can be seen below in Table 3.

Table 3. Correlation Coefficients Between Skin Temperature and Temperature Perception

	Cammie		MOPP	
	TP1	TP2	TP1	TP2
Head Skin 1	.09		-.02	
Head Skin 4		.16		.02
	Cammie		**MOPP**	
	TP1	TP2	TP1	TP2
Chest 1	-.03		-.13	
Chest 4		.49**		-.04
	Cammie		**MOPP**	
	TP1	TP2	TP1	TP2
Thigh 1	-.11		-.07	
Thigh 4		.31*		.26*

* = $p < .05$; ** = $p < .01$

Note: TP was not recorded during the second and third five minute periods of the treadmill walk.

As can be seen in the Table 3, temperatures taken at individual skin sites do not correlate highly with temperature perception regardless of the type of clothing worn. Apparently, in order for skin temperature to correlate highly with temperature perception, a mean skin temperature value must be used. Mean skin temperatures are either weighted (according to the mass of different body sections) or unweighted, and use anywhere from four to 15 measuring sites Mitchell and Wyndham (1969). In the Gagge et al. (1969) study, an unweighted 10-site method was used.

CONCLUSIONS

For subjects marching 20 minutes out of every hour, for 12 hours, carrying up to 50% of their bodyweight, or carrying 75% of their bodyweight for six hours under ambient conditions (75°F and 50% relative humidity), it can be concluded that:

1. Rectal temperature does not increase to levels associated with thermoregulatory distress when subjects wear camouflage combat clothing or MOPP4 chemical warfare clothing.

2. Rectal temperature is not highly correlated with temperature perception. In the present study, correlation coefficients ranged between -.24 and .39.

3. While temperature perception may be highly correlated with mean skin temperature, it is not highly correlated with individual skin temperatures taken at the forehead, deltoid fold on the right side of the chest, and the front thigh.

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THE EFFECTS OF PACKLOAD AND CHEMICAL DEFENSE CLOTHING ON THE PERCEPTION OF EFFORT

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ABSTRACT

Sixteen males (mean age = 23 years) volunteered as subjects. A repeated-measures design was used as subjects walked on a treadmill 20 minutes each hour at 3 mph, for up to 12-hours, with packload [0, 25, 50, 75% of body weight (BW)] and uniform [cammie (C) or chemical defense gear (CDG)] conditions randomized for eight, in-lab tests at ambient temperatures of 24^{o}C. Data on energy cost (kcal/hr), heart rate (HR), and perceived exertion (RPE) were collected. The results showed that kcals/hr increased in proportion to load, with only the 0% BW loads being different ($p < .05$) for the two clothing conditions. CDG had small, insignificant effects on energy cost. However, heart rate was four to nine bts/min higher in the CDG for the four loads as compared to the C for each successive load. The HR increased in a curvilinear fashion between 50% and 75% BW for both C and CDG. The RPE scores reflected kcal/hr cost, workload and HR (i.e., increased from low to high loads). Only the RPE scores for the 0% BW were different ($p < .05$) between C and CDG. It was concluded that in a thermal neutral environment, and at moderate work, energy cost is closely related to the total load carried, and that CDG minimally increases HR (due to shunting blood to the periphery for cooling), and is barely reflected in the perception of effort.

Portions of this material were previously presented at the 1989 Medical Defense Bioscience Reviews, John Hopkins University, August 5-7, 1989, and published in the Proceedings of the 1989 Medical Defense Bioscience Review, U.S. Army Medical Research Institute of Chemical Defense.

INTRODUCTION

The energy cost (kcals/hr) of load carriage has been shown to be primarily dependent upon the load carried, and the velocity and grade of the subject who carries the load. Moreover, the heart rate will increase more for a standard exercise when done in a warm environment as opposed to a thermal neutral one [i.e., 20-24°C and a relative humidity (RH) of 40-50%] (McArdle et al., 1986). The Borg scale of perceived exertion (RPE), which allows the rating of effort for various exercise situations, is based on heart rate (HR), and has been found to be valid for a variety of tasks. For instance, Yeager et al. (1987) has shown that as packload was increased for subjects walking on a treadmill, RPE scores increased proportionately for loads to 50% of their body weight. Teitlebaum and Goldman (1972) have reported that wearing multi-layered clothing, as with wearing chemical defense gear (CDG), requires an increased energy expenditure beyond what would be predicted based on its weight alone. Thus, the purpose of this study was to determine: 1) the energy cost of walking with packloads up to 75% of body weight; and 2) to assess the combined effect of exercise, packload, and clothing on HR and RPE.

METHODS

Sixteen, fit males (mean age = 22.8 years; mean weight = 74.1 kg; mean height = 179.4 cm) served as subjects for this study. Their relative body fat averaged 10.3%, and their mean aerobic capacity (VO_2 max) was 61.5 ml/kg/min, STPD. All the subjects had been doing aerobic training for at least six months prior to testing. Packload was determined after weighing the subjects while wearing only shorts. The Alice pack, which housed the weights (lead shot in bags), and uniforms were considered as part of the load. The loads and clothing conditions were randomly assigned to each subject. The exercise consisted of a 20-min walk on a level treadmill each hour for up to 12 walks. A 60-minute break for lunch and hygiene after the 6th walk was allowed. Energy cost was determined by spirometry using a Rudolph valve to shunt the expired air through a corrugated tube (id. 2.8 cm) into a 5-liter mixing chamber, and finally, through a dry gas meter (Rayfield). The expired air was sampled from the mixing chamber at a rate of 300 ml/min. Applied-electrochemistry oxygen and CO_2 analyzers were used to determine the fraction

of expired O_2 and CO_2, respectively. The analog voltage scores from the gas meter and analyzers were converted to digital values, and recorded on a floppy disk for later analysis. The oxygen uptake scores were converted to kcals/hr units by using the respiratory quotient caloric value, times the liters of oxygen used. The HR was measured continuously by an electrocardiogram (ECG) scope, and was also recorded on a floppy disk for later analysis. The Borg scale (RPE) was presented to the subjects during the first and last two minutes of each exercise session, and at the midpoint of recovery periods (20 minutes following exercise). The RPE scores in this report are the averages of the two exercise measures for all sessions by load and clothing condition. The clothing conditions consisted of the standard Marine Corps cammie uniform (C) and CDG NBC uniforms (CDG). For both clothing conditions, subjects wore exercise shoes rather than boots. The M17A2 mask along with gloves, a hood, heavy jacket, trousers, and rubber overboots were used for the CDG condition.

RESULTS

The energy cost for the two clothing conditions at zero load (actually the load was 3 or 8% of BW, for C or CDG, respectively) was different ($p < .05$) with means (standard deviations) of 260(39) vs. 303(45) kcals/hr, respectively. The mean loads for the 25%, 50%, and 75% of body weight were 18.5, 37.1, and 55.6 kgs, respectively. Therefore, the average subject moved a total mass of 76.3 (body weight + cammies) or 80.0 (body weight + CDG), 92.6, 111.2, and 129.7 kgs (see Table 1) while walking on the treadmill at relative loads of 3 or 8%, 25%, 50%, and 75% of body weight. The energy cost was linear with packload throughout the load range with no clothing differences at 25%, 50%, and 75% BW loads (see Figure 1). The pooled means were 324(39), 393(60), and 465(66) kcals/hr, respectively. As seen in Table 1 and Figure 2, HR scores increased linearly from 0% to 50% BW loads, but demonstrated a greater increase between the 50% and 75% BW loads.

As with energy costs, the only HR differences between C and CDG were found at the 3 or 8% BW load ($p < .05$). As shown in Table 1, the RPE scores also rose linearly throughout the packload range and, as with energy cost, the lone clothing difference was at the 3 or 8% BW load condition.

TABLE 1. HR AND BORG SCALE (RPE) SCORES BY LOAD AND CLOTHING

Clothing	Cammies		CDG	
Load (%BW) (Kg)	HR (bts/min)	RPE	HR (bts/min)	RPE
3 or 8 76.3 or 80.0	87 (11.8)	8.2 (1.5)	96 (19.3)	9.8 (1.4)
25 92.6	103 (19.2)	10.5 (2.1)	107 (28.7)	11.1 (1.9)
50 111.2	108 (18.8)	13.3 (1.5)	115 (18.8)	13.5 (1.7)
75 129.7	128 (24.5)	15.2 (1.7)	135 (24.3)	15.0 (1.7)

Values represent the means (standard deviations)

Figure 1. Energy cost in kcals/hr for four different packloads while walking on a level treadmill at 3.0 mph in regular uniforms (cammies) and chemical defense gear. The horizontal line across the bottom of the graph represents the typical energy cost of resting for young adult males.

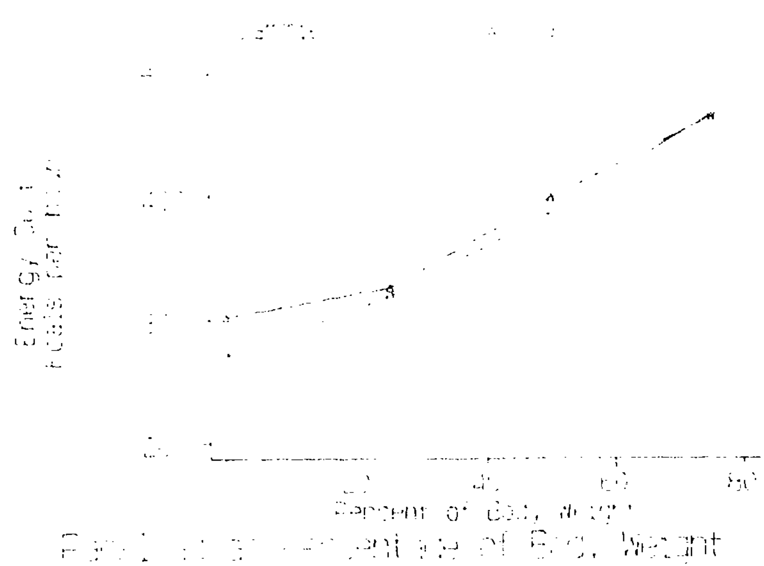
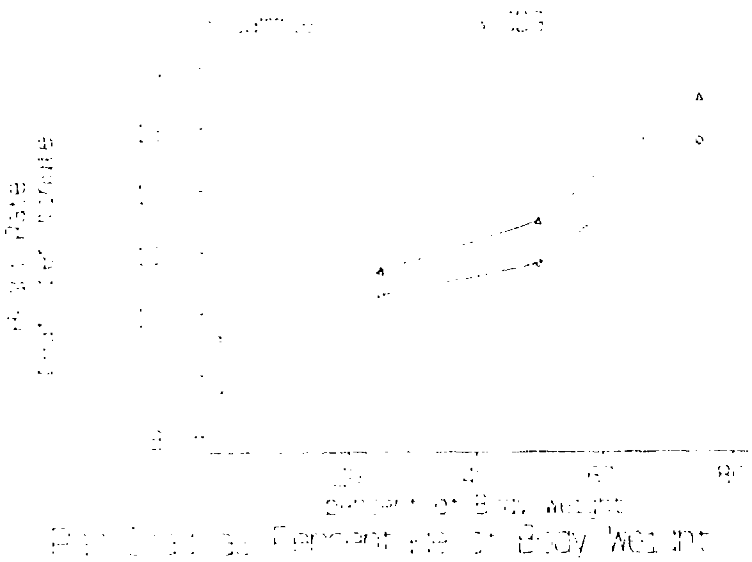


Figure 2. The relationship of heart rate and packload for the chemical defense gear clothing conditions.



DISCUSSION AND CONCLUSIONS

The energy costs for this study are similar to the results of Wallcott et al. (1986) in that both investigations found a linear relationship between packload and energy cost. The above-cited study measured VO_2 for 17 middle-aged males, and found mean kcal values for walking at 3.5 mph with loads of 0% to 40% BW on a level treadmill. However, when adjusted for weight and speed differences, the energy costs for the present study are 9% lower than scores reported at 0% and 25% BW by Wallcott et al. (1986) for the cammie condition. This difference could be attributed to higher fitness levels of the subjects used in this study.

This study did not support the results of Teitlebaum and Goldman (1972) and Duggan (1988) who found that an energy cost increase in excess of the added 4% weight of the protective clothing. Both of the above-cited studies suggest that the increased energy costs of the protective clothing (about 4%) could be due to hobbling caused by the bulkiness and stiffness of the

clothing, and interference with movements; frictional resistance was also mentioned as a possible cause. The present findings of no increase in kcals/hr in excess of the cammie condition could be due to improved walking economy resulting from many miles of aerobic training for the fit subjects. Also, since the subjects wore only one layer of clothing (trousers and shirts), whether C or CDG, there would be little increase in bulkiness and stiffness and no more frictional resistance than while wearing cammies. However, wearing the rubber boots during the CDG conditions one could expect reduced economy, but on a treadmill, at a comfortable walking speed, the increase would likely be minimal.

The HR score comparisons yielded similar results for those found for energy cost. Although not statistically significant, HR was consistently 4 to 9 bts/min higher in the CDG condition. The higher HR scores for the CDG, though a small increase, may reflect the greater shunting of warm blood to the periphery in an attempt to cool the body via convection and evaporation. Increased core temperature with increased workload is consistent with the literature (McArdle et al., 1986) as is the slightly higher temperatures for the same work rate in heavier clothing (Avelline, 1983). Avellini (1983) showed that male subjects walking at 3.0 mph in cammies increased their rectal temperature to a steady state of 37.5°C, while in the CDG condition it leveled off at 37.75°C. When the current HR results are adjusted to equivalent loads and speeds used in the Wallcott et al. (1986) study, they are about 10% lower. This finding of higher HR for the Wallcott et al. (1986) study is expected for subjects of older age and lower aerobic fitness (45.7 ml/kg/min vs. 61/5 ml/kg/min for the current subjects) as they would be working at a higher fraction of their VO_2 max and HR max.

The RPE response increased in proportion to the increasing packload. Except for the 3 or 8% BW load, the clothing conditions produced quite similar results. As with the HR findings, the RPE scores are slightly but not significantly greater for the CDG uniform. From the 50% to the 75% BW load, the RPE and HR do not show consistent changes as the HR increased an average of 19%, while the RPE increased only 12.7%.

We conclude that the energy cost, workload, heart rate, as well as, clothing combine to influence the perception of exertion when walking with light to very heavy packloads. However, the packload was clearly the most influential factor.

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COMBAT HEADGEAR EFFECTS ON REACTION TIME, EXERTION, AND THERMAL PERCEPTION

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ABSTRACT

The NB Mark II combat helmet with attached SBF Mark 72 ballistic face shield, an advanced protective headgear, has been proposed for shipboard use. The effect of wearing the 6-lb. headgear continuously for eight hours was investigated for a decrement in physical and cognitive performance. Eight, healthy male volunteers, Navy shipboard personnel (means: age = 25.2 yrs, height = 180.2 cm, weight = 168.0 lbs.), were studied. Subjects were tested on two separate days, one week apart; once, while wearing the headgear, and once without. Simple reaction time (RT) scores were measured as part of a 20-min microcomputer Performance Assessment Battery (NHRC-PAB). The Borg scale and the U. S. Army Institute of Environmental Research (USARIEM) heat scale were used to determine perceived exertion (RPE) and thermal perception (TP), respectively. Exercise sessions consisted of a 20-min treadmill walk at 3 mph (0% grade). RPE and TP scores were recorded pre- and post-exercise sessions (N = 8). RT tasks were administered during three sessions (S1, S4, and S7). A repeated measures design was employed with headgear (HGEAR/NO HGEAR). and test day (TDAY1/TDAY2) variables randomly assigned. Headgear wearing and test day yielded no levels of significance for RT, RPE, and TP scores ($p > .05$) except for a test day by headgear interaction ($p < .05$). There were significant session RPE and TP effects ($p < .05$), however, session scores increased for both the headgear and no headgear conditions. These results suggest that wearing the NB Mark II helmet/SBF Mark 72 shield did not cause a decrement in physical nor cognitive performance.

INTRODUCTION

A new protective headgear has been proposed for use aboard Navy ships by the Naval Dental Research Institute, Great Lakes, Illinois. The NB Mark II combat helmet with attached SBF Mark 72 ballistic face shield was designed to decrease the frequency, as well as reduce the severity of facial injuries due to fragmentation projectiles. The Naval Health Research Center's Sustained Operations Department in San Diego, California, was contracted to conduct a pilot study on this prototype headgear.

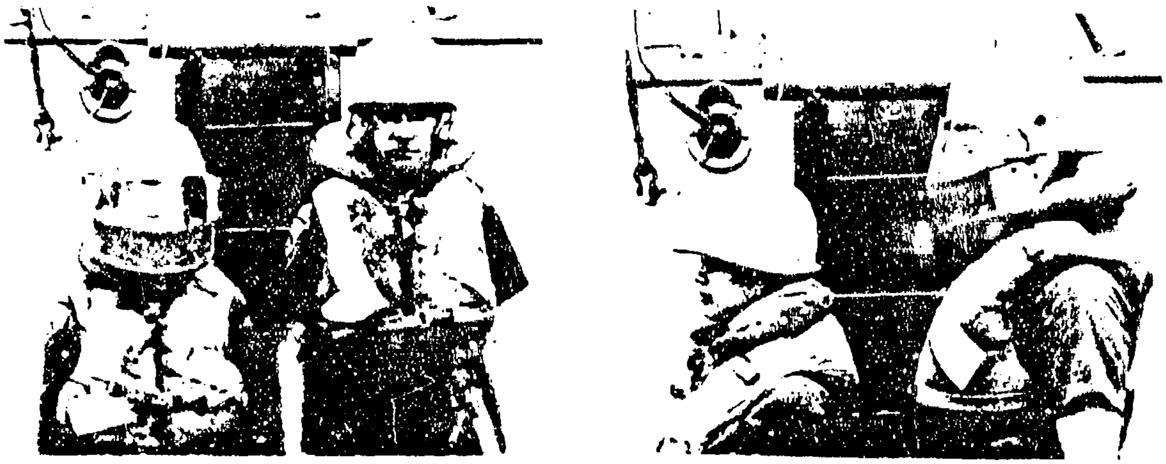
The NB/SBF headgear has a combined weight of six pounds, and consists of three main parts: 1) the helmet, 2) the shield (both helmet and shield are made of kevlar, and sealed with a layer of fiberglass to prevent water damage), and 3) the transparent visor portion of the shield which is made of polycarbonate and coated with an anti-abrasive silicone compound. The entire headgear was ballistic-tested in a fragmentation projectile simulator against a .22 caliber, 17-grain machine-chiseled-point projectile. The helmet and shield exceeded the required military V_{50} ballistic rating of 1400 feet per second, and the visor exceeded the required military V_{50} ballistic rating of 650 feet per second.

Although twice the weight of the older Navy M1 combat helmet (a World War II steel pot design), this new headgear affords the wearer greater head, face and jaw protection (Figure 1). The face shield and jaw-guard may be worn in a raised position, however, this alters the designed balance of the headgear. The head and neck area may become uncomfortable if the headgear is worn in the raised position for a considerable length of time.

PURPOSE

The purpose of this study was to investigate the effects of wearing the NB Mark II combat helmet/SBF Mark 72 ballistic face shield on human performance.

FIGURE 1. NB/SBF AND M1 COMBAT HEADGEAR



METHODS

Eight healthy, male, Navy-Shipboard personnel volunteered as subjects (Table 1). Testing took place in the laboratory at the Naval Health Research Center (NHRC) on two occasions approximately one week apart. On the first test day (TDAY 1), half of the subjects wore the new headgear and half wore no headgear. The headgear wearing condition on the second test day (TDAY 2)

TABLE 1. SUBJECT PHYSICAL CHARACTERISTICS (N = 8)

Variable		Mean	Std Dev	Minimum	Maximum
Age	(YR)	25.3	4.132	21	34
Height	(CM)	180.6	5.673	172.7	187.6
Weight	(KG)	76.2	10.209	61.8	88.9
Skinfolds	(MM)				
Triceps		9.3	4.384	3	16
Subscapular		10.8	4.114	5	15
Iliac Crest		8.4	4.458	3	14
Abdominal		17.3	9.010	5	27

was reversed. Selection for the headgear condition TDAY 1 was randomized. Each subject, wearing work clothes and boots, wore the headgear continuously for an 8-hr time period interrupted only for a 30-min lunch break at the end of hour 4. Each 4-hr block was divided into 1-hr sessions making a total of 8 test sessions per test day. All test sessions included a 20-min walk on a treadmill at 3 mph and 0% grade, and a 20-min computer task.

Simple Reaction Time (SRT), part of the NHRC Performance Assessment Battery (Ryman et al., 1983), was evaluated during three sessions (S1, S4, and S7). The SRT task required the subject to strike the keypad as soon as a clock, pictured on the monitor, began to display incremental time. The computer starts the clock (start interval varies trial-to-trial), and the subject attempts to stop the clock as quickly as possible.

The 6-20 Borg Scale (Borg, 1985) was used to rate perceived exertion, (RPE), and the U. S. Army's Institute of Environmental Medicine's (USARIEM's) 0-8 Thermal Sensation Scale (Young et al., 1987) was used to score thermal perception (TP). Both scales are displayed in Figure 2.

FIGURE 2. PERCEPTION SCALES

BORG'S RPE SCALE		THERMAL SENSATION SCALE	
6	NO EXERTION AT ALL	0.0	UNBEARABLY COLD
7	EXTREMELY LIGHT	0.5	
8		1.0	VERY COLD
9	VERY LIGHT	1.5	
10		2.0	COLD
11	LIGHT	2.5	
12		3.0	COOL
13	SOMEWHAT HARD	3.5	
14		4.0	COMFORTABLE
15	HARD (HEAVY)	4.5	
16		5.0	WARM
17	VERY HARD	5.5	
18		6.0	HOT
19	EXTREMELY HARD	6.5	
20	MAXIMAL EXERTION	7.0	VERY HOT
		7.5	
		8.0	UNBEARABLY HOT

Laboratory conditions were monitored to maintain a constant temperature of 21°C and 50% humidity. Each scale was recorded pre/post all eight treadmill exercise sessions.

A repeated measures design was employed with test day (TDAY1, TDAY2), headgear condition (HGEAR, NO HGEAR) and session (SESS 1 to SESS 8) as variables.

RESULTS

The breakdown of mean SRT trials for each session wearing the HGEAR vs. NO HGEAR are displayed in Table 2.

TABLE 2. MEAN REACTION TIMES - ALL TRIALS BY SESSION

NO HGEAR					
Variable	Mean	Std Dev	Minimum	Maximum	Trials
Sess 1	.559	.169	.22	2.20	436
Sess 2	.561	.157	.38	2.31	430
Sess 3	.574	.193	.32	2.85	430
HGEAR					
Variable	Mean	Std Dev	Minimum	Maximum	Trials
Sess 1	.564	.133	.22	1.75	422
Sess 2	.596	.192	.00	1.82	432
Sess 3	.593	.194	.22	2.14	423

A Multivariate Analysis of Variance (MANOVA) performed on SRT scores investigating Test Day, HGEAR condition, and Session effects showed no significance or interaction ($p > .05$).

A breakdown of mean RPE scores split by HGEAR condition is displayed in Table 3. The pre/post value is the difference between the pre-exercise RPE score and the post-exercise RPE score. Figure 3 illustrates mean pre/post RPE scores displayed by HGEAR condition and Session.

TABLE 3. MEAN RPE SCORES - ALL PRE/POST SESSIONS

Variable	Mean	Std Dev	Minimum	Maximum	Sessions
NO HGEAR					
Pre-exercise	10.4	1.687	6.0	13	64
Post-exercise	11.0	1.627	7.0	14	64
Pre/Post Diff	.6	1.003	0.0	4	64
HGEAR					
Variable	Mean	Std Dev	Minimum	Maximum	Sessions
Pre-exercise	10.6	1.597	7.0	14	64
Post-exercise	11.3	1.666	7.0	15	64
Pre/Post Diff	.6	.919	0.0	4	64

FIGURE 3. MEAN PRE/POST RPE SCORES BY HGEAR AND SESSION

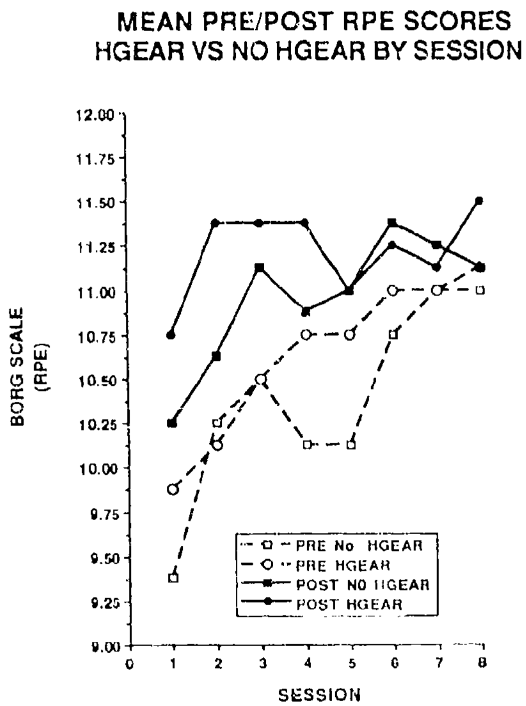


Figure 3.

A MANOVA performed on pre-exercise RPE scores showed no significance or interaction ($p > .05$) except for a Session effect which showed a significant p value of 0.0. Post-RPE analysis showed no significant effects ($p <. 05$) except for a HGEAR by TDAY interaction ($p < .05$).

A breakdown of mean Thermal scores is displayed in Table 4. The pre/post value is the difference between the pre-exercise TP score and the post-exercise TP score.

TABLE 4. MEAN THERMAL SCORES - ALL PRE/POST SESSIONS

NO HGEAR					
Variable	Mean	Std Dev	Minimum	Maximum	Sessions
Pre-exercise	3.8	.503	2.5	5.0	64
Post-exercise	4.5	.534	3.0	5.5	64
Pre/Post Diff	.6	.545	0.0	2.0	64
HGEAR					
Variable	Mean	Std Dev	Minimum	Maximum	Sessions
Pre-exercise	4.1	.590	2.0	5.0	64
Post-exercise	4.8	.672	3.0	5.5	64
Pre/Post Diff	.7	.546	0.0	2.0	64

Figure 4 illustrates mean pre/post thermal scores displayed by HGEAR condition and Session. A MANOVA performed on pre/post-exercise TP scores showed no significance or interaction ($p > .05$) except for both a pre- and post-Session effect ($p < .05$).

DISCUSSION

Wearing the 6 lb. headgear did not affect SRT performance. SRT scores with the HGEAR (mean = .584) were slower than without the HGEAR (mean = .565), however, the delta was not statistically significant.

The only significant headgear effect was on post-exercise RPE scores. Both groups of subjects, those who wore the headgear on TDAY1 and those who

FIGURE 4. MEAN PRE/POST THERMAL SCORES BY HGEAR AND SESSION.

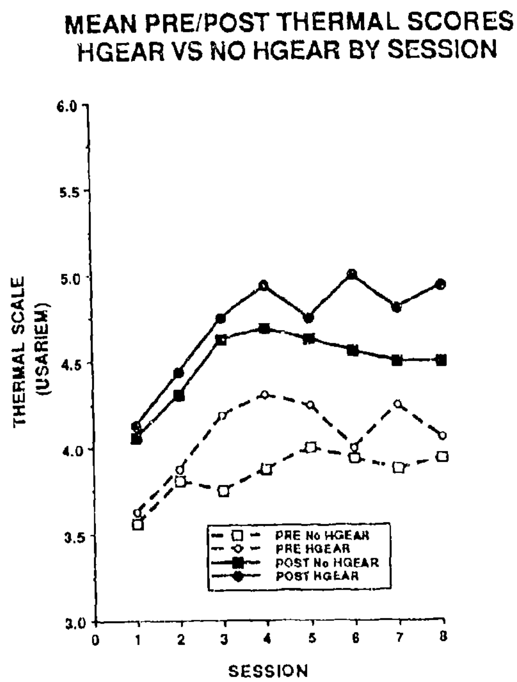


Figure 4.

wore the headgear on TDAY2, rated their post-exercise RPE scores higher when the headgear was worn. Mean post-exercise RPE scores grouped by subjects wearing or not wearing the HGEAR on TDAY1 and TDAY2 are displayed below in Table 5.

Table 5. MEAN POST-RPE SCORE BY TDAY BY HGEAR

TDAY1	11.88	NO HGEAR	10.25	HGEAR
TDAY2	12.19	HGEAR	10.03	NO HGEAR

Although the RPE scores between HGEAR and NO HGEAR were statistically different ($F = 9.41$, $p = .018$), the difference (TDAY1 = .31; TDAY2 = .22) was not thought to be physiologically relevant.

Thermal scores with the HGEAR were higher than scores with no HGEAR, however, the deltas were not statistically significant. There was a significant Session effect for both pre-TP ($F = 2.58$, $p = .026$) and post-TP ($F = 3.88$, $p = .002$) scores. Figure 4 shows TP scores increased throughout SESS 1 to SESS 4, and maintained that elevated level from SESS 4 to SESS 8. The rise in thermal scores was expected as each successive exercise session was completed throughout the test day. Since the head area is a major source of heat loss, and the headgear covered practically the whole head and face region, it is important to note that while wearing the headgear, TP scores did not increase significantly higher than the TP scores while not wearing the headgear.

CONCLUSIONS

It was concluded that for the subjects involved in this investigation, wearing the NB Mark II combat helmet and SBF Mark 72 face shield for eight hours did not cause a significant decrement in Reaction Time performance. Although Perceived Exertion and Thermal Perception scores were different when wearing the HGEAR, the delta between scores was not statistically significant. Further research is needed to investigate if harder work loads or extreme temperature conditions will adversely affect human performance while wearing this headgear.

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EVENT-RELATED POTENTIALS DURING SUSTAINED OPERATIONS

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The previous papers that have been given during this session have already described the who, what, where, and why of sustained operations (SUSOPS) research. The goal of the present paper is to provide some support for an area of technology that may address the issue of HOW to evaluate human performance during sustained operations.

Although the technology I'll be discussing can address any operational community such as radar or air traffic control, I've chosen to investigate the performance of sonar operators. I've chosen sonar for four reasons: 1) sonar operators are routinely placed in SUSOPS situations; 2) the sonar population is readily accessible to our laboratory - the only sonar school is located in San Diego; 3) we are investigating this population in other ongoing research projects at the Naval Health Research Center (NHRC); and 4) I know the most about this type of operational performance (I was a sonar operator for nine years).

Most people think of sonar as purely an aural task. The operator is "listening for pings." However, Getty and Howard (1981) have pointed out in their book on auditory pattern recognition that sonar operation is much more complex as is shown in Figure 1. Sonarmen are tasked not only with detecting the signal associated with the target, but also discriminating between multiple auditory signals so as to track the appropriate signal. Although you might get some appreciation for how complex the signal processing task is for a sonar operator from this Figure, it is somewhat dated. Modern sonar operation is a very complex task. Operators are actually participating in multiple tasks and receive information through various sensory systems (see Figure 2). Sonar operators, for example, not only receive the complex auditory information as discussed above, but also receive a redundant form of this information through the visual modality. In addition, these operators are tasked with maintaining verbal communication with their supervisor, as

well as receiving somatosensory information from ship motion and vibrating equipment. Therefore, many things may affect performance especially when the operators are tasked to perform under extended or continuous operations.

Figure 1. Sonar Operators must discriminate between various sources of information to determine which signal is target-relevant (taken from Getty and Howard, 1981).

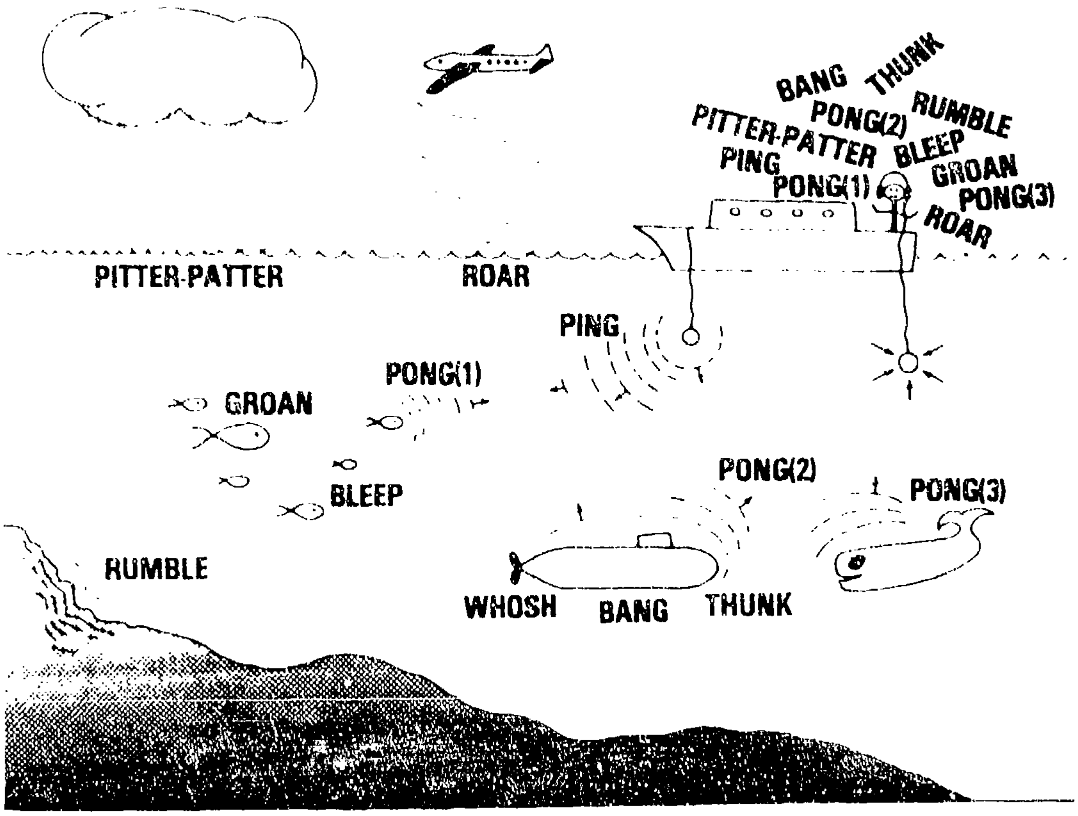
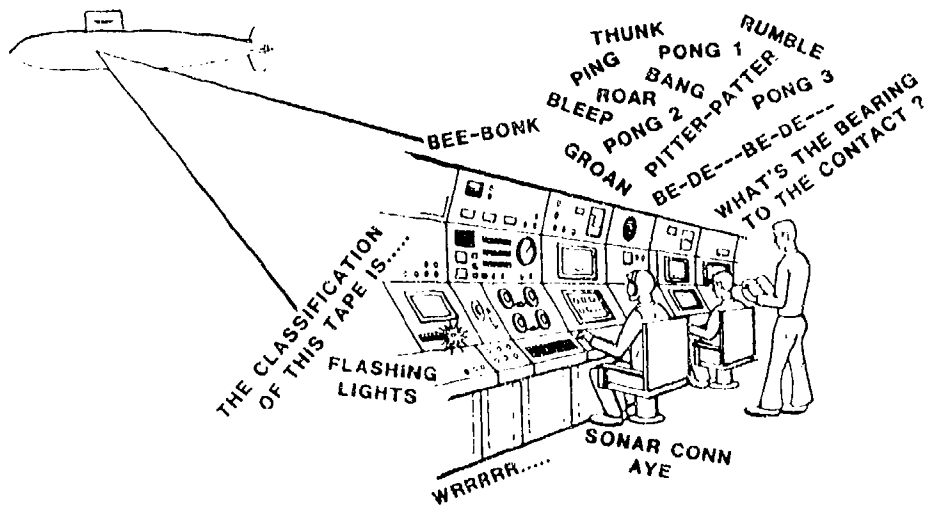


Figure 2. The advances in display technology presently provide the sonar signals to multiple modalities for further processing by the operator.



It is very difficult to collect data in such a highly complex environment. How can you evaluate performance in such an environment? Where do you begin? One approach, is to go directly to the operators, and ask which stressors appear to be affecting their performance the most. This was the method chosen by Mackie (1987). They provided a list of possible stressors which affect performance (see Table 1) to 300 sonar operators from various communities (Surface, Submarine, and Air). The task of each operator was to rank-order the stressors according to their effect upon performance.

The stressors used probably affect most visual display terminal (VDT) operators. Table 2 shows how each community ranked each of the stressors. Note the similarity of each list. The top five ranked stressors are almost identical for each group.

Table 1. **Stressors Expected to Affect Operator's Performance**

Risky Peacetime Operations	Fatigue, Tiredness
Platform Motion	Threat of Enemy Action
Command Pressure	Air Contamination
Boredom, Monotony	Displays/Controls
Lighting	Illness
Heat	Air Pressure
Noise	Motion Sickness
Vibration	Cold
Workstation Design	Night Watch-Standing
Operator Overload	

Table 2. **Average Rankings of the Adverse Impact of 19 Stressors on Overall Sonar Operator Effectiveness (worst listed first).**

Submarine Operators	*Surface Ship Operators*	*Helicopter Operators*
1. Boredom, monotony	1. Boredom, monotony	1. Fatigue, tiredness
2. Fatigue, tiredness	2. Fatigue, tiredness	2. Boredom, monotony
3. Command pressure	3. Displays/controls	3. Displays/controls
4. Displays/controls	4. Night watch-standing	4. Operator overload
5. Operator overload	5. Command pressure	5. Command pressure
6. Workstation design	6. Operator overload	6. Workstation design
7. Heat	7. Workstation design	7. Vibration
8. Illness	8. Noise	8. Noise
9. Noise	9. Illness	9. Cold
10. Air contamination	10. Motion sickness	10. Lighting
11. Lighting	11. Lighting	11. Heat
12. Night watch-standing	12. Heat	12. Platform motion
13. Cold	13. Platform motion	13. Illness
14. Air pressure	14. Cold	14. Motion sickness
15. Platform motion	15. Air pressure	15. Night watch-standing
16. Motion sickness	16. Vibration	16. Risky peacetime ops
17. Vibration	17. Risky peacetime ops	17. Air contamination
18. Risky peacetime ops	18. Air contamination	18. Threat of enemy action
19. Threat of enemy action	19. Threat of enemy action	19. Air pressure

Source From Wylie, Mackie, and Smith (1985)

Table 3 is a chart which lists perceived impact that each of the stressors will have upon operational performance, and the knowledge base that the scientific community has regarding the impact that each stressor has upon human performance. As can be seen, we have an insufficient knowledge base on four out of the top five stressors to determine how each may effect performance. One reason for this lack of knowledge is that good techniques have not been developed which are useful in the operational environment. The reason for this is that most times, experimental protocols interfere with operational performance.

Table 3. Relationship Between Judged Impact and State of Knowledge for 19 Stressors.

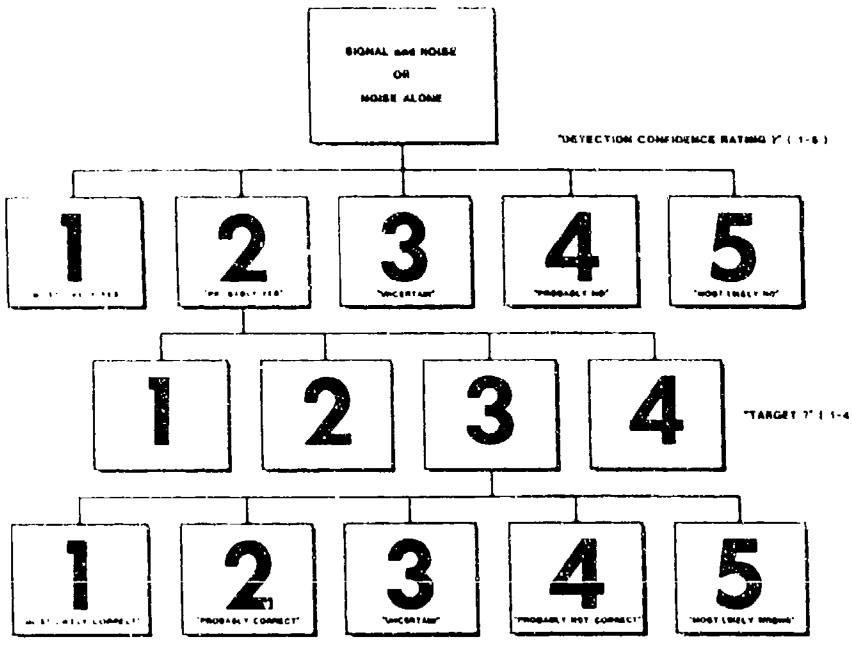
	JUDGED IMPACT ▷	HIGH	MEDIUM	LOW
CURRENT STATE OF KNOWLEDGE (Linkage to performance)	INSUFFICIENT	1.* Boredom 2. Fatigue 4. Command pressure 5. Operator overload 19. Danger from enemy action	11. Minor illness 13. Motion	14. Vibration 15. Motion sickness 16. Air contamination 17. Risky peacetime operations 18. Uncomfortable air pressure
	ADEQUATE	3. Display/Control design 6 Work station/ personal equipment design	7. Midwatch (circadian effects) 8. Heat 9. Noise 10. Illumination 12. Cold	

So, the question is, "How do you evaluate performance in a complex environment without disrupting operational performance?" This is where the technology of electrophysiology, specifically, the event-related potential (ERP), may be most useful. These potentials are small electrical signals recorded from various sites on the scalp that were timelocked with the stimulus onset. the primary advantage of this technique is that it can be used in the absence of any behavioral response.

The following is a brief description of some of our earlier work using the ERP to monitor human performance. The first study was based on the

findings of Parasuramen, Richer, and Beatty (1982). They determined that the ERP, along with a behavioral measure could be useful in predicting detection and recognition performance during an auditory task. They found that the N100 was correlated to detection performance whereas the P300 was highly correlated to both detection and recognition performance. They concluded that their data supported the notion that detection and recognition are overlapping processes. Our experiment followed the same basic paradigm, but investigated the visual modality. An additional modification was the use of a double confidence rating procedure. Figure 3 provides a block diagram of the possible response alternatives.

Figure 3. A flow diagram displaying the various response alternative for a two-level confidence rating signal detection experiment.



The subjects used in the study were all highly-experienced sonar operators, each with a minimum of four years of operational experience. Each subject was a volunteer, and participated until 2800 artifact free trials were recorded. Figure 4 shows what the noise background looked like to all

operators. Whereas, Figure 5 displays what the noise plus target looked like. Four separate targets were used. Each target consisted of four vertical lines which varied in their spacing. This task had tremendous face validity when compared to an actual sonar display.

Figure 4. The visual display presenting "noise background" data only.

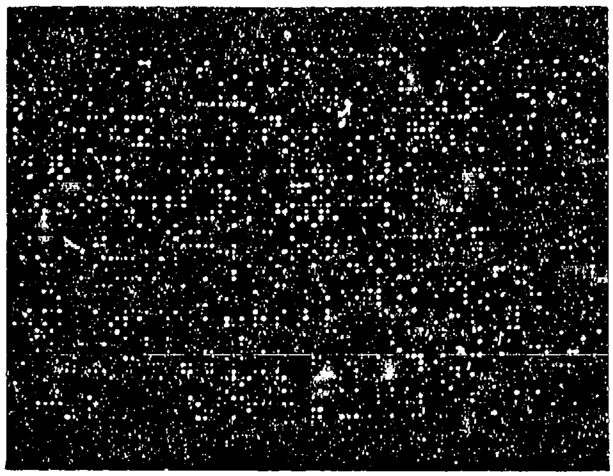
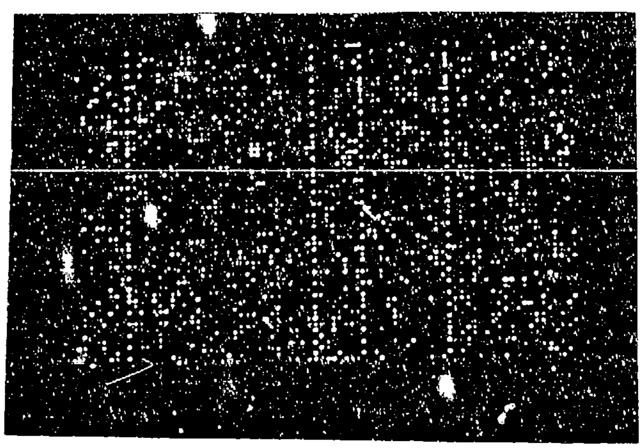
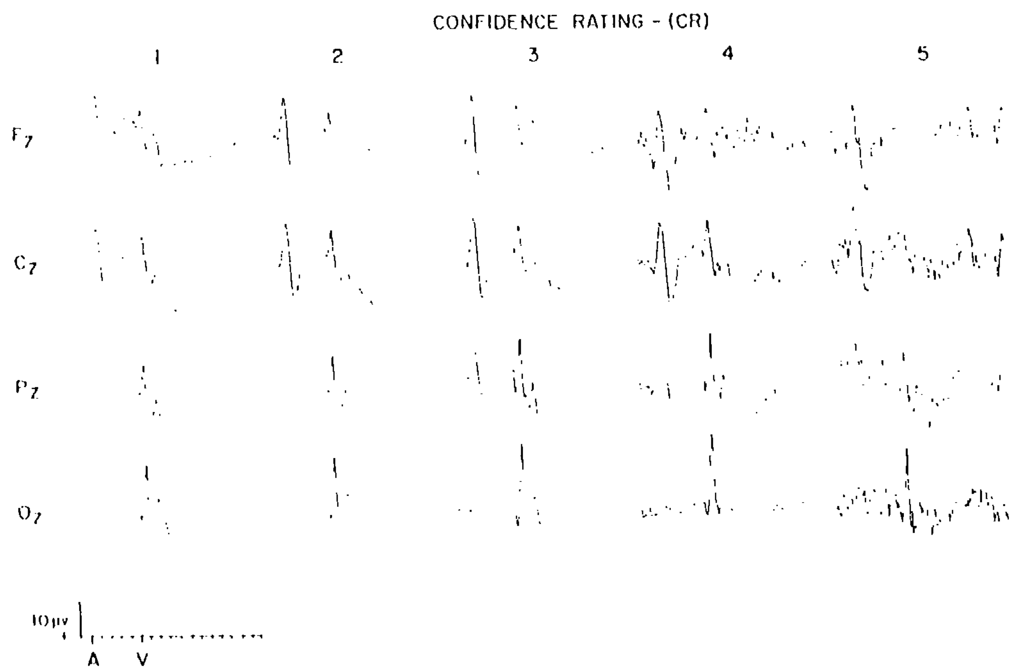


Figure 5. The visual display presenting target information plus background.



The results were very similar to that of the Parasuramen et al. (1982) study. The electrophysiological waveforms are shown in Figure 6. The N100 was correlated to detection performance, whereas, the P300 was found to be correlated to recognition performance. Amplitude of the components were greater when confidence was high (the left side of Figure 6) and decreased as the confidence of making a correct detection/recognition response decreased. Somewhat of a serendipitous result is also evident in Figure 6. Note the large component which is a result of the auditory warning tone (far left of each waveform). This component was significantly larger at the FZ (frontal) electrode site as compared to the other sites. Normally, the amplitude of these components are largest at the PZ (parietal) electrode site for naive subjects. However, the subjects in this experiment were not naive, but were highly-trained sonar operators. Therefore, this result prompted another experiment investigating the morphology of the ERP of highly-experienced subjects during an auditory discrimination task.

Figure 6. Signal detection task grand average event-related potentials for all eight subjects across five detection confidence levels for each electrode site.



The results of this study suggested the distribution of electrical activity in (on) the brain may change as a function of training or experience (see Figure 7). These changes may be indicative of different processing strategies between trained and untrained individuals. Such results may have tremendous implications for training. However, in retrospect, there were some confounding variables which may also be responsible for the results. One possibility is that aging may be responsible for changes in the distribution of electrical activity of the brain. However, the age groups differed by less than a decade. Another possibility is that the greater activity at the frontal site was due to eye movements since they were not monitored during this task. Therefore, another study was conducted controlling for age and monitoring eye movements. The task was similar to the above mentioned study in which subjects were to discriminate between two auditory tones. Figure 8 displays the results of this investigation. Age did appear to influence the distribution of electrical activity. The older, naive group displayed larger amplitude at the frontal site as compared to the young, naive group. However, the age-matched experienced subjects demonstrated the greatest activity at the frontal site.

Figure 7. Grand average event-related potential data for an auditory oddball task demonstrating site differences between trained and untrained sonar operators.

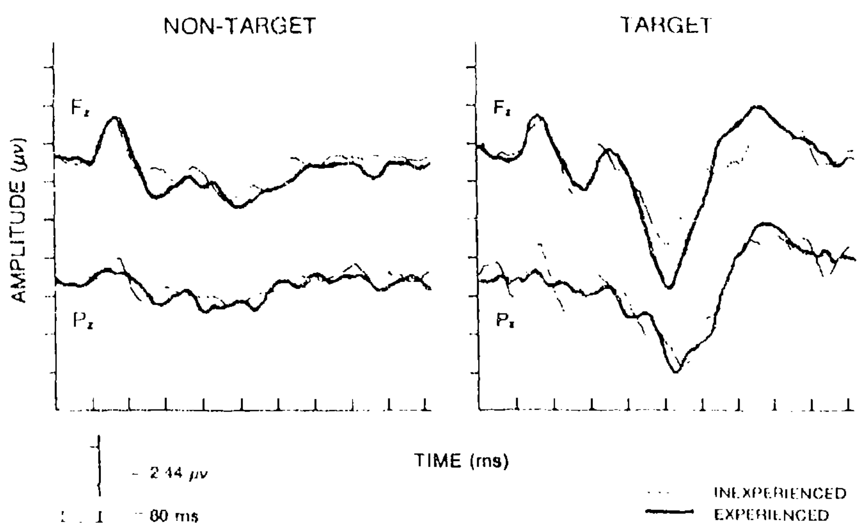
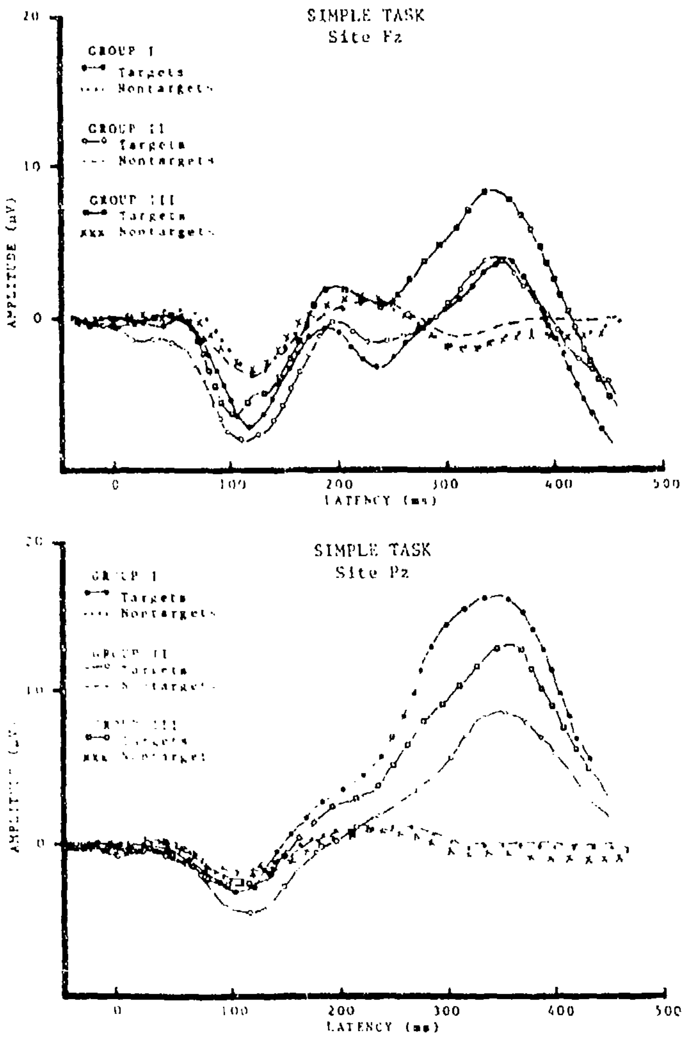


Figure 8. Grand average waveforms for each group, site and stimulus condition. (Group I = young untrained subjects; Group II = older untrained subjects; Group III = older experienced subjects).



These results have important implications for operational evaluation of human performance, as well as, evaluating various training techniques. However, thus far, the methodology discussed has utilized electrophysiology as a dependent measure in a task that would still be somewhat obtrusive.

The Naval Health Research Center is currently extending this research as an unobtrusive measure of operator performance. The latest work includes investigating the Human Steady-State Response. Basically, this technique provides a low-intensity, 40Hz tone to the subject in addition to the ongoing task. The subject is not required to respond to the tone in any way. The brain, however, appears to respond to the signal in a way which allows the evaluation of general alertness 40 times per second. When the operator is alert, the amplitude of the 40Hz response is large. Yet, when the operator begins to doze off, the amplitude of this response decreases. We are presently investigating whether or not such a technique would be feasible to monitor general alertness of pilots.

In summary, the recent advances in computer power and system portability make the use of electrophysiology an ideal tool for the unobtrusive monitoring of human performance. It will only be a matter of time before electrodes are built into the headsets of sonar operators, or the helmets of pilots, to provide an electrophysiological interface between man and machine.

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SUBJECTIVE ASSESSMENT OF PHYSICAL COMPLAINTS DURING SUSTAINED OPERATIONS

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ABSTRACT

The effects of continuous work have been investigated in a series of seven studies with different scenario demands of human endurance. Subjects alternated each hour between bouts of exercise and non-exercise during which both physical and mental performance were measured. These studies have included manipulations of sleep loss (48-hours with work break), physical work (0-40% of VO_2 max), load carry (0-75% of body weight), type of protective clothing (MOPP 1-4) and combinations of these conditions. Measures of physical effort, physiological and psychological status, and cognitive performance were taken either continuously or every hour. One segment of the Performance Assessment Battery (PAB) includes a computerized version of the Subjective Fatigue Feelings Scale (SFF) which we have used to determine the subject's perception of physical symptoms experienced during progression of the study. The results indicated significant increases in fatigue and symptoms as a function of work load, shift, and work/rest schedule, clothing, and time of day. This research has important implications for identifying and developing methods for sustaining and enhancing performance under arduous conditions.

INTRODUCTION

Our research concerning cognitive performance has spanned several years. At first, the emphasis was directed at understanding circadian effects and the benefits of interpolated naps during long continuous work episodes. The naps were of various lengths taken at different times of a day during mental work segments lasting for up to 60-hours (Naitoh, 1981). The nap and circadian research is still underway (Naitoh and Angus, 1987). It soon became obvious,

however, that these studies were potential simulations of a larger set of work experiences in both civilian and military life, in particular, emergency situations and combat (Englund et. al., 1985). Our research expanded from the study of "fragmented" sleep to CONOPS (Continuous Operations) and SUSOPS (Sustained Operations) (Englund and Krueger, 1985; Krueger and Englund, 1985). As the research progressed, in addition to loss of sleep, the effects of physical work, load carry and work rate, thermal conditions, medications, and diet became of interest as factors implicated in performance effectiveness. Additionally, new questions and methodologies emerged from these, as well as that of others' investigative experiences and findings, such that studies about cognitive performance and psychophysiology began to include a wide variety of interdisciplinary measures involving biochemical and work physiology factors. Standardized cognitive and physical performance assessment batteries (PABs) were developed by Tri-Service committees as a means of cross comparison between laboratories and studies (Englund et al., 1987).

Many of the independent variables of interest in SUSOPS studies, such as, respiratory and thermal reactions, can be assessed directly. Several other factors, important in sustained work effectiveness, and reflecting underlying intervening constructs such as motivation, reasoning, and fatigue, are measured by assessing the subject's perception of the effect on his performance on tasks. These indirect measures consisted of paper and pencil and computerized checklists, mood scales, and performance tasks. One such instrument we have used to indicate the type and frequency of physical and fatigue symptoms during SUSOPS studies is the Subjective Fatigue Feelings (SFF) scale introduced in 1970 by the Industrial Fatigue Research Committee of the Japan Association of Industrial Health (Saito et al., 1970; Kogi et al., 1970). The questionnaire has been used numerous times by Japanese scientists to determine the subjective feelings of fatigue by workers in various occupations in Japan (Saito and Matsumoto, 1988; Kogi, 1970). This paper presents the results from the SFF data across studies and factors.

METHODS

The major factors thought to influence cognitive and physical performance are fatigue, work load, temperature, and time-of-day. This has required, in

the study of sustained work, the manipulation of sleep and rest breaks, SUSOPS start time, and mental, physical work, and thermal loads. Designs for our studies have, as a result, been multivariate with repeated measures. The pervasive factor built into the protocol (Figure 1) is the continuance of the work performed by the participants. The sleep factor consisted of baseline, a work break consisting of a nap or rest (rest length = nap length) and recovery sleep segments. Physical work consisted of calibrated treadmill walking, carrying given pack loads. The thermal load was produced by subjects wearing Individual Protective Ensembles (IPE) for chemical warfare. Ambient temperature conditions were held at 21.1°C and 50% humidity. The SUSOPS nature of the studies was accomplished by 30-minute per hour alterations of physical and cognitive work accomplished continuously over two, 24-hour back-to-back episodes as prescribed by the protocol. Figure 1 is a generic protocol typically followed in our SUSOPS studies. This protocol allows for task and performance training, baseline testing for both physical and cognitive capacity, and laboratory familiarization to be accomplished immediately prior to the start of the simulated SUSOPS. Additionally, the protocol is flexible, allowing for the length (up to 48-hours) and number of work day episodes (2), rest/nap (0, 3, and 4 hours) periods, and operational start times (0800, 1300, or 2400) to be manipulated. Work and thermal loads were varied by clothing type (IPE or no IPE), walking rate [0-40% of maximal oxygen uptake (VO_2 max)] and load carry amounts [0-75.% of body weight (BW)]. Not all of these factors were manipulated in the same study. This presentation covers the results across seven studies, six of which were conducted at the Naval Health Research Center (NHRC) and the seventh accomplished at San Diego State University (SDSU).

For the NHRC Studies, pairs of informed male volunteers (age 18-35, n = 58, moderate to high fitness levels) representing a broad sample of the Marine Corps population participated in each week-long study. They were divided into exercise and non-exercise groups. After arrival at the lab early Monday morning, each pair would progress through a series of training and testing periods. Tuesday's schedule was a continuance of the baseline testing activities except for Study 1. In Study 1, the Marines experienced a 12-hour continuous work episode followed by an eight-hour sleep period on Tuesday. As

EXPT'L PHASE	MONDAY Training		TUESDAY Baseline		WEDNESDAY CW1		THURSDAY CW2		FRIDAY Recovery	
TIME	WA	WB	WA	WB	WA	WB	WA	WB	WA	WB
00 - 01							15A	15B	15A	15B
01 - 02							16A	16B	16A	16B
02 - 03							17A	17B	17A	17B
03 - 04			SLEEP Ø		SLEEP 1				ETS Task	
04 - 05										
05 - 06							SLEEP 2		SLEEP 3	
06 - 07	TRAVEL									
07 - 08			BREAKFAST*							
08 - 09	Forms		1A	1B	1A	1B	1A	1B		
09 - 10	Max VO_2 Testing		2A	2B	2A	2B	2A	2B		
10 - 11			3A	3B	3A	3B	3A	3B		
11 - 12	LUNCH**		4A	4B	4A	4B	4A	4B		
12 - 13	Computer Task Trn		LUNCH						LUNCH	
			5A	5B	5A	5B	5A	5B		
13 - 14			6A	6B	6A	6B	6A	6B		
14 - 15	ADG Training†		7A	7B	7A	7B	7A	7B		
15 - 16			8A	8B	8A	8B	8A	8B		
16 - 17	DINNER		SUPPER							
17 - 18	Computer Task Trn		9A	9B	9A	9B	9A	9B		
18 - 19			10A	10B	10A	10B	10A	10B		
19 - 20	N-D Read.††		11A	11B	11A	11B	11A	11B		
20 - 21	ADG Training†		12A	12B	12A	12B	12A	12B		
21 - 22			SNACK**							
22 - 23	Word Mem.		ETS Task EEG Hookup		13A	13B	13A	13B		
23 - 24	SLEEP Ø		SLEEP 1		14A	14B	14A	14B		
					15A		15A			

CW = Continuous Work
*Includes time for attachment of ECG electrodes and rifle assembly task.
**Includes time for rifle assembly task.
† Air Defense Game
†† Nelson Denny Reading Test

Figure 1. Chronological Work Schedule for Subjects By Day

in the remainder of the studies, Wednesday and Thursday were the SUSOPS (or extended work) episodes. Normal sleep periods were usually given Monday, Tuesday, and Thursday evenings. The SUSOPS work periods were divided into two, 24-hour episodes separated by a rest or nap period. Instrumentation consisted of computerized Cognitive Performance Assessment Battery (PAB) stations and equipment commonly used in exercise physiology laboratories, i.e., treadmills and respiratory gear. During each hour of the SUSOPS WORK schedule, exercise subjects alternated between 20-30 minutes of treadmill walking and 20-30 minutes of PAB testing, breaking only for short meals and rest/nap periods. While the exercisers were walking on the treadmill, they also performed a visual vigilance task. At the same time, the non-exercisers performed all of the same tasks, but did so while seated at a computer terminal.

The SDSU research, contracted by NHRC, observed 16 subjects in a crossover design with eight conditions. College students with high-to-marathon fitness levels walked on treadmills 20 minutes per hour for up to 12 hours while carrying packloads weighing 0, 25, 50, 75.% of BW, and wearing either standard military field gear or IPE. The remainder of the hour was spent performing computer or paper and pencil-administered tasks.

The SFF is a 30-item questionnaire (see Table 1) requiring only a yes or no response depending upon whether the item applies or not. The questionnaire is divided into three, 10-item components corresponding to: (1) Drowsiness-Dullness (items 1-10); (2) Concentration Difficulty (items 11-20); and (3) Projection of Physical Disintegration (items 21-30). It was presented each hour as part of the computerized PAB, however, only the total number of responses was recorded per work day for all but the first NHRC Study.

Four statistical packages for the social sciences (SPSSX) multivariate analysis of variance (MANOVAs) were performed to determine which, if any, experimental conditions may have influenced responses to SFF statements. The first MANOVA analyzed Sleep (2) by Day (2) by Exercise (3) conditions across Studies 1-4. The second analysis looked at Start time (3) by Day (2) by Workload (3) across Studies 1, 5, and 6. A descriptive analysis was also conducted as a result of findings in the first two procedures which indicated

that it might be beneficial to examine work load effects by half-day segments of each Continuous Work episode. The third MANOVA was performed on the SDSU data, and analyzed Work Load (4) and Clothing (2) by grouped Sessions (3) conditions.

TABLE 1

	CW1	CW2	Difference
Drowsiness-Dullness	554	856	302
Concentration-Difficulty	265	467	202
Physical Problems	374	486	62
Total	1193	1759	566

RESULTS

Figure 2 depicts the results of the analysis which examined the effects of rest or nap, exercise (0, 30, 40% of VO_2 max) and successive continuous work episodes (CW1 and CW2), over Studies 1 through 4. Significant Day (F (2,50) = 50.56, p = .000), and significant triple interaction (F = 4.33, p = .018) between exercise, rest type, and day effects were found. This meant that complaint frequency increased significantly the second continuous work day as a function of work load interacting with work break type. Figure 3 exemplifies the dramatic effects of the 40% VO_2 max work load over the 30% VO_2 max work load, and the differences of resters over nappers.

Figure 4 shows the results of analyzing SUSOPS start time (0800, 1300, 2400), exercise (0, 30, 40% of VO_2 max), and Day (CW1 and CW2) effects. The analysis covered Studies 1, 5, and 6. Subjects worked either sedentary or 30% VO_2 max physical work loads and all were give a 3-hour nap after the first CW day. Significant exercise condition (F(2,49) = 5.82, p = .020) and Day (F(2,49) = 17.34, p = .000) effects were found. This meant that complaints were once again higher during the second CW day, and significantly greater for those with 1300 and 2400 operational start times.

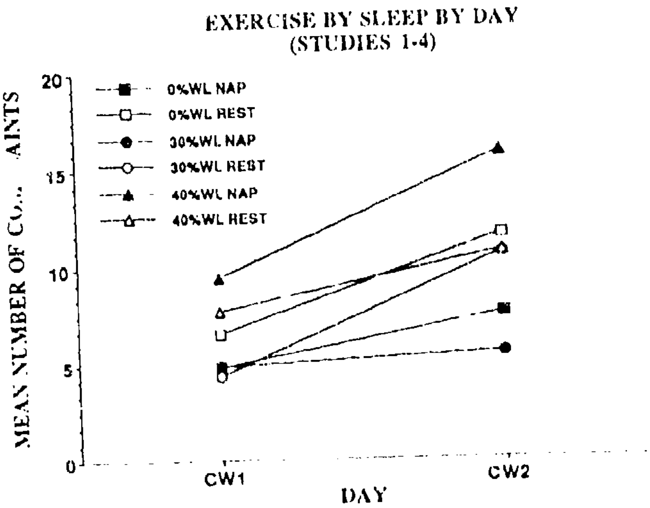

Figure 2. Mean Physical Complaints for Continuous Work Sessions One (CW1) and Two (CW2) For Selected Work Loads (WL) and Nap or Rest Intervals

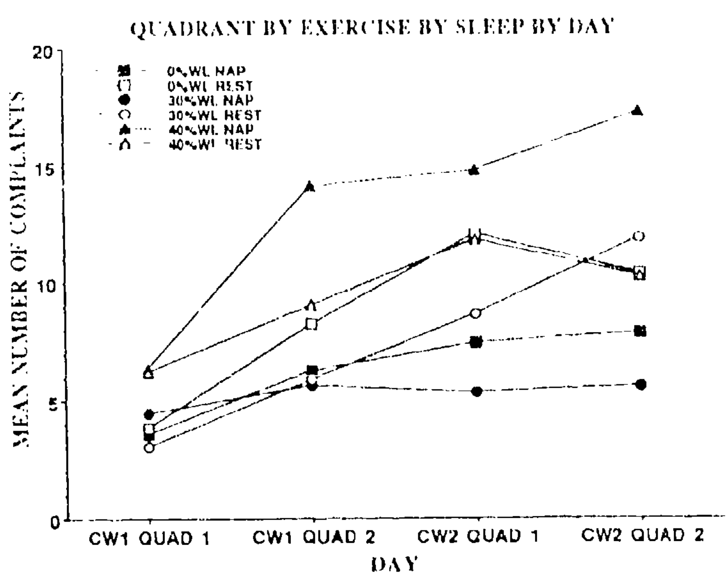

Figure 3. Mean Physical Complaints for Continuous Work Sessions (CW) by Quadrant. A Quadrant Equals the Average Response for Each Half of Each CW. Groups are Based on Work Loads (WL) and Nap or Rest Interval.

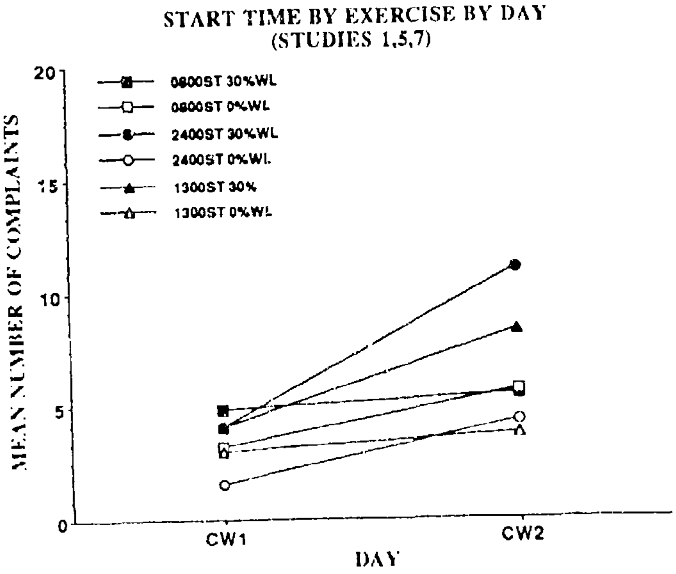

Figure 4. Mean Physical Complaints for Continuous Work Sessions (CW) by Start Time, Day, Work Load (WL) and Nap or Rest Interval.

Figure 5 indicates the results of the SDSU study which examined 12 hours of periodic physical work in regular or IPE military clothing with packloads ranging up to 75% of BW. Significant main effects were found for Clothing ($F(1,7) = 17.32$, $p = .05$), Packload ($F(3,21) = 5.11$, $p = .05$), and Sessions for either clothing or packload conditions. This meant that working in IPE (MOPP 4) gear produced more complaints than working in the usual military combat clothing. Also, as packload (particularly 50% BW packload and above) and work time increased so did the complaints.

Table 1 is the response profile from Study 1, and represents the combined frequency count for both exercisers and non-exercisers. Although numerous complaints were reported over the first 24-hour work episode, there were significantly more complaints indicated over the second, 24-hour work episode by all participants (1193 vs. 1759). A larger number of complaints were associated with the Drowsiness-Dullness factor than either of the other two factors.

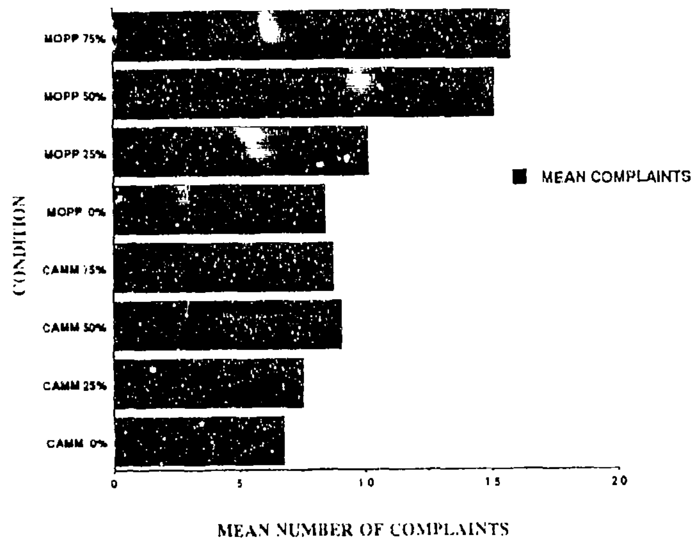

Figure 5. **Mean Physical Complaints for Continuous Work Sessions for the SDSU Study by Clothing [Military Operational Preparedness Posture (MOPP)] and Regular Work Uniforms (CAMM) and Packload as a fraction of the Subjects' Body Weight.**

DISCUSSION

It appeared that the worst of all conditions was to be a 40% VO_2 max napper, whereas, the best was the 30% VO_2 max nap work assignment. Additionally, although the 30% VO_2 max nappers and resters started out with an equal number of complaints on the first continuous work day, the resters did not fare as well on the second CW day. In general, the nappers, except for the 40% VO_2 max group had fewer complaints on the second CW day than the resters. Except when the physical work load was too great, as was the case for the 40% VO_2 workers, a 3- or 4-hour nap seemed to reduce complaint frequency by comparison to the resters. In fact, considering that the nap was effective for the other groups, more study of high work load and work/rest relationship is in order.

Starting an operation at either 1300 or 2400 the previous day, was significantly more debilitating on the second CW day than an 0800 start time.

The 2400-hour start time apparently produced the strongest negative reaction. Both the alternate shift groups had been phase-shifted to adjust the Marines to the operation time.

At increased packloads, and with the addition of IPE gear, combat effectiveness is compromised. By the third hour, except for the 40% VO_2 max nappers on their second continuous work day where it was about equivalent, the complaint frequency was higher for the high packload conditions than any other group in any of the other studies. The significant change in performance, as measured by complaint frequency, appeared at the 50% BW packload. Zero and 25% BW packloads were equivalent, however, significantly different than the 50 and 75% BW packloads which were also equivalent. Interestingly, 0 and 25% BW packloads with IPE gear were rated similarly to the 50 and 75% BW packloads without IPE. The 50 and 75% BW packloads with IPE showed the highest complaint frequency of any group including the 40% VO_2 max nappers. Another interesting fact is that at the 50% BW packload level, subjects were unable to complete the mission of 12, one-hour sessions. On the average, those in cammies completed 10.2 sessions and those in IPE only 9.9. At the 75% BW level, the mission had to be cut to a six-session objective which was not met by most of the volunteers (mean = 5.4 and 5.1, respectively). In the NHRC 40% VO_2 max workload study, nearly one-half of the subjects could not complete the second CW day.

It would appear that fatigue and sleepiness were responsible for most of the complaints. In an earlier paper (Ryman et al., 1987), responses to the SFF were reported to be correlated with ratings on Borg's Perceived Exertion Scale (Borg, 1977), with more reliable correlations observed at lower levels of exercise than at higher exercise loads. Englund (1986) previously reported that complaint frequency for either CW day was modulated by a circadian cycle. Rhythm amplitude increased as a function of the increase variability of complaint frequency on the second CW day, and appeared to possibly shift slightly in phase, with some desynchronization. The latter observation requires further confirmation.

The use of a simple checklist like the SFF requires further evaluation before it can be accepted as a reliable predictor of a person's performance

status. The data from the SFF would indicate that a continuous work load not to exceed 30% VO_2 max with a nap of at least three hours somewhere in the work/rest cycle, is the most for the soldier/sailer who must meet a continuous work challenge. Work loads greater than 30% of VO_2 max for continuous periods are not recommended, particularly when IPE and/or high packloads may be required. In terms of work breaks taken at the circadian low point of a work shift (in this case 0400), opportunity for a nap of at least three or more hours is better than just resting for those with work loads less than 30% of VO_2 max. It would also appear from the data that the use of some physical activity interspersed in the work/rest cycle for all workers particularly sedentary workers, may be a good method for precluding aches and pains.

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It is with considerable appreciation that this acknowledgment is given to Ms. Valerie Loewe and Mr. Greg Norman for their contributions to the analysis of the data discussed in this paper.

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OPTIMISM AND CARDIOVASCULAR REACTIVITY TO
PSYCHOLOGICAL AND COLD PRESSOR STRESS

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Abstract

The relationship between optimism, as measured by the Life Orientation Test (LOT), and the response to mental arithmetic (MA) and cold pressor (CP) stressors was examined in 35 men. Reactivity measurements included heart rate (HR), systolic (S) and diastolic (D) blood pressure, oxygen consumption (V), minute ventilation (VE), and plasma cortisol (CORT). In order to clarify the importance of optimism to reactivity, additional assessments were made for hostility, depression, behavior type, and trait anger and anxiety. Both stressors elicited significant cardiovascular, pulmonary and cortisol responses ($P < 0.005$) with the magnitude of response being greater for the CP task. Significant Pearson correlations were found between LOT and CP reactivity for VE ($r = -.285$, $P < 0.05$), and MA reactivity for HR ($r = .281$, $P < 0.05$) and VE ($r = .374$, $P < 0.01$) yet the results suggest that optimism was not strongly associated to reactivity elicited by either stressor. However, results did indicate that the relationship between optimism and cardiovascular reactivity may be as important as those exhibited by other psychological parameters.

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The purpose of the symposia was to present findings exemplary of some of the more recent interdisciplinary SUSOPS studies conducted at the Naval Health Research Center, San Diego, California. The symposia began with a presentation about the U.S. Navy SUSOPS Research Program and issues of field performance assessment. Next was a discussion of sustained heavy work loads on both temperature and perception of thermal effects. Closely related, was a presentation on sustained work effort and actual energy cost. Reaction time, work effort, and thermal perceptions as a function of wearing the Navy's new shipboard Combat Helmet and Face Shield for sustained periods was the subject matter of the next presentation. Use of event-related potential techniques to study attention and performance during sustained tasks was presented next. An in-depth discussion was presented on the results of measures of Medical and Psychological problems which typically have plagued military participants over a series of sustained operations studies. Lastly, results of a Navy SUSOPS Study of Physiological reactivity and optimism as a function of stress was presented.

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